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terms of  $n$  other quantities  $b_1, \dots, b_n$ , then is the space of the first quantities identical with that of the last quantities. But if the  $n$  quantities  $a_1, \dots, a_n$  can be expressed in terms of less than  $n$  quantities  $b_1, \dots, b_n$ , then  $a_1, \dots, a_n$  are not independent, and some of them can be numerically expressed in terms of others.

20. Two quantities of a space of the  $n$ th order are equal to each other when and only when their numerical coefficients of the same units are equal. This is analogous to the algebraic theorem which says that two complex numbers are equal only when their real parts are equal and also their imaginary parts.

21. If the coefficients  $x_1, \dots, x_n$  by which an extensive quantity  $x$  is expressed in terms of the units  $e_1, \dots, e_n$  satisfy an equation of the  $m$ th degree  $f(x_1, \dots, x_n)=0$ , then the coefficients  $y_1, \dots, y_n$  by which  $x$  is expressed in terms of  $a_1, \dots, a_n$  of the same space also satisfy an equation of the  $m$ th degree, and if the first equation is homogeneous, the latter is also.

PROOF. Let  $a_1 = \sum \alpha_{1r} e_r, \dots$ . Then we have

$$x_1 e_1 + x_2 e_2 + \dots + y_1 \sum \alpha_{1r} e_r + y_2 \sum \alpha_{2r} e_r + \dots = \sum y_r \alpha_{r1} \cdot e_1 + \sum y_r \alpha_{r2} \cdot e_2 + \dots$$

$$\therefore x_1 = \sum y_r \alpha_{r1}, \quad x_2 = \sum y_r \alpha_{r2}, \quad \dots \quad (\text{Art. 20}).$$

But if these values are substituted in  $f(x_1, \dots, x_n)=0$ , we get an equation of the  $m$ th degree in  $y_1, y_2, \dots$ , and, indeed, homogeneous if the first equation is homogeneous.

[To be Continued.]

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## DEPARTMENTS.

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### SOLUTIONS OF PROBLEMS.

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#### ARITHMETIC.

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112. Proposed by G. B. M. ZERR, A. M., Ph. D., Professor of Mathematics and Science, Chester High School, Chester, Pa.

The cost of an article is  $\$4.\frac{.297}{1.002}$ . The selling price is  $\$6.\frac{1.000}{.33337}$ . What is the gain %?

I. Solution by COOPER D. SCHMITT, A. M., Professor of Mathematics, University of Tennessee, Knoxville Tenn., and the PROPOSER.

$$297 = \frac{297}{999} = \frac{11}{37}; \quad 1.003 = 1\frac{1}{300} = \frac{301}{300}.$$

$$\frac{11}{37} \div \frac{301}{300} = \frac{3300}{11137}; \quad \frac{3300}{11137} = \frac{330}{1113.7}.$$

$$\therefore \$4. \frac{297}{1.003} = \$4.11137 = \$4.11137 = \text{cost price.}$$

$$\$6. \frac{1000}{33337} = \$6.33337 = \$6.33337 = \text{selling price.}$$

$$\therefore \$6.33337 - \$4.11137 = \$2.22200 = \text{gain.}$$

$$(\frac{22200}{1000000}) \text{ of } 100\% = 2.22\%.$$

Also solved by O. S. WESTCOTT and ALOIS F. KOVARIK.

113. Proposed by B. F. SINE, Principal of Normal School, Capon Bridge, W. Va.

In what time can a note of \$5280, bearing 6% interest, be paid by paying \$600 a year? [Solve by arithmetic].

Solution by WALTER H. DRANE, Graduate Student, Harvard University, Cambridge, Mass.

Let  $Q$  be the principal,  $r$  the rate,  $n$  the number of years, and  $P$  annual payment. Then

$$Q(1+r) = \text{amount due at end of first year.}$$

$$Q(1+r) - P = \text{principal to run second year.}$$

$$Q(1+r)^2 - P(1+r) = \text{amount due at end of second year.}$$

$$Q(1+r)^2 - P(1+r) - P = \text{principal to run third year.}$$

$$Q(1+r)^n - P(1+r)^{n-1} - \dots - P(1+r) - P = \text{amount to run } (n+1)\text{th year.}$$

But the debt is cancelled. Hence

$$Q(1+r)^n - P(1+r)^{n-1} - \dots - P(1+r) - P = 0.$$

$$\therefore P \left[ \frac{(1+r)^n - 1}{r} \right] = Q(1+r)^n.$$

$$\therefore (P - Qr)(1+r)^n = P.$$

$$\therefore n = \frac{\log P - \log(P - Qr)}{\log(1+r)}.$$

In the problem  $P = \$600$ ,  $Q = \$5280$ ,  $r = .06$ .

$$\therefore n = \frac{\log 600 - \log(600 - 5280 \times .06)}{\log(1.06)} = 12.88 \text{ years.}$$

Also solved by G. B. M. ZERR, COOPER D. SCHMITT, and J. SCHEFFER.

## ALGEBRA.

93. Proposed by CHARLES C. CROSS, Whaleyville, Va.

Given  $x^x + y^y = 285$ , and  $y^x - x^y = 14$ , to find the values of  $x$  and  $y$ . [From *Bonnycastle's Algebra*, 1841].

I. Solution by A. H. BELL, Hillsboro, Ill.

The two equations give

$$(285 - y^y)^y = (y^x - 14)^x \dots (1).$$